E
378.748
P051897.7

LIBRARY OF THE UNIVERSITY OF PENNSYLVANIA

E378.748

POS1897.7

GIFT OF

Univ.

The Venturi Meter.

by

Theodore H Bunker.

Bunker '97

A Venturi Meter.
68

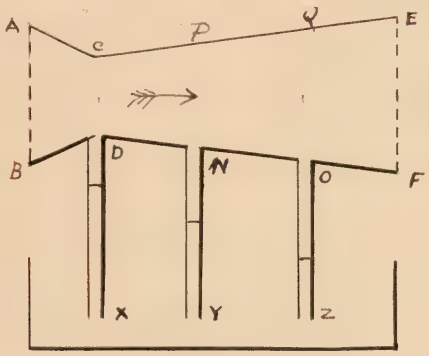
E 378.748
POS 1897.7

B., T.

31 May 48 Sci. & Eng.

The Italian philosopher Citizen J. B. Venturi in a series of experiments conducted at Modena about 1791 observed, as one of the curious phenomena developed in his work, that a sucking action occurs at the throat or narrowest section of a venturi, causing a vacuum proportional to the velocity of flow through the venturi.
His apparatus comprised a reservoir in which a constant head was maintained on an orifice to which the venturi shown in the figure I was attached. The converging and diverging tubes were made of

tinned iron and three glass tubes DX, NY, and OZ carefully fitted in at the points shown all joints being carefully smoothed.



When water was permitted to pass through AEFB the mercury rose 3 lines in the tube DX, 20.5 in NY and 7 in OZ. These were the equivalent to 6 in 0 + and 8.1 inches of water. The difference of 38 inches elevation of water in the two tubes DX and NY was caused by the motion of the fluid from C to P. "The stream decreases as it moves

point CD so [illegible]
[illegible] made in
many [illegible]
[illegible]
[illegible] within the tube
[illegible] compressed [illegible]
with [illegible] [illegible]."

Lenard seems to have made no
further application of
[illegible] to Clerk Maxwell's
[illegible] hydrodynamical [illegible]
[illegible]
[illegible]
[illegible] conclusions of
[illegible]
[illegible] Lenard's
[illegible].

As described by its inventor the Venturi meter is "an instrument to gauge the quantity of water flowing in a given time, measured by an adjustable orifice expansion in the system of pipes."

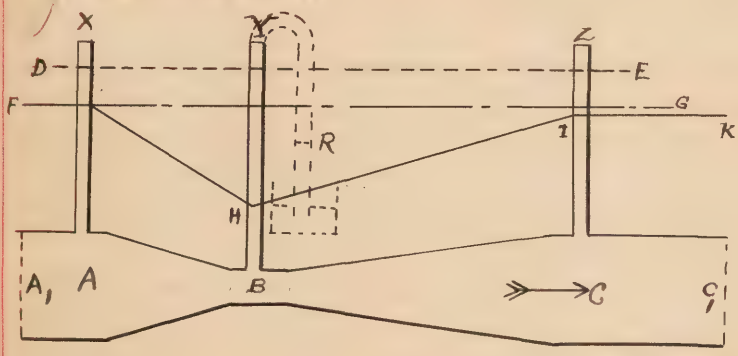


Figure 2.

The meter consists essentially of a short converging tube A and a longer diverging tube C connected by a short throat B, cylindrical in form, constituting the "venturi" proper.

If the fluid is at rest in the tube under a static pressure the

piezometer tubes X, Y and a will be filled to the same height by the liquid and a column of the liquid equal in height to the column of liquid in the tube X will be produced in the direction of the arrow DE. Now suppose a low pressure in the direction of the arrow to be produced in tube X and a column of liquid equal to $\frac{v^2}{2g}$ will be produced in the tube Y and a column equal to the total pressure

$$h = \frac{v^2}{2g} + h'$$

where h is the total hydraulic head, h' the pressure head or height of liquid in the piezometer tube. Suppose a flat plate placed in the stream of liquid in a direction at right angles to the stream of liquid

[illegible]

[illegible]

[illegible] B will be [illegible] A.

[illegible]

X. [illegible] H

[illegible]

[illegible] B.

[illegible] B o C [illegible]

[illegible]

[illegible] of [illegible] column X and

[illegible] length [illegible] between [illegible] A

and C [illegible]

[illegible] the [illegible] F H I K.

The depression at the top may
come to great a [illegible]
-tum of liquid in one X [illegible]
in the [illegible] circulating in
[illegible] other. If a magnet
Y were [illegible] around a
[illegible] could be [illegible]
[illegible] the column
of fluid [illegible]
[illegible] X [illegible]
[illegible]
the order in [illegible]
[illegible].

I [illegible] perhaps be [illegible] from
what has been said that of one
method could be devised, on
measuring the difference in level
between the columns of mercury
in the pigmented tubes X and Y
[illegible] magnet is present

termed "the head on the venturi", the data so obtained might be used in gauging the quantity of flow through the meter.

A photograph of the two inch Venturi meter in the laboratory of the University of Pennsylvania is shown in figure 4. An annular chamber A is shown at the up stream end of the meter and a similar chamber at the throat B. These pressure chambers are connected by eight inch piping through three way cocks and air chambers to the manometer tube shown at M and N in figure 4. There is a photograph of the apparatus as used in the following series of experiments.

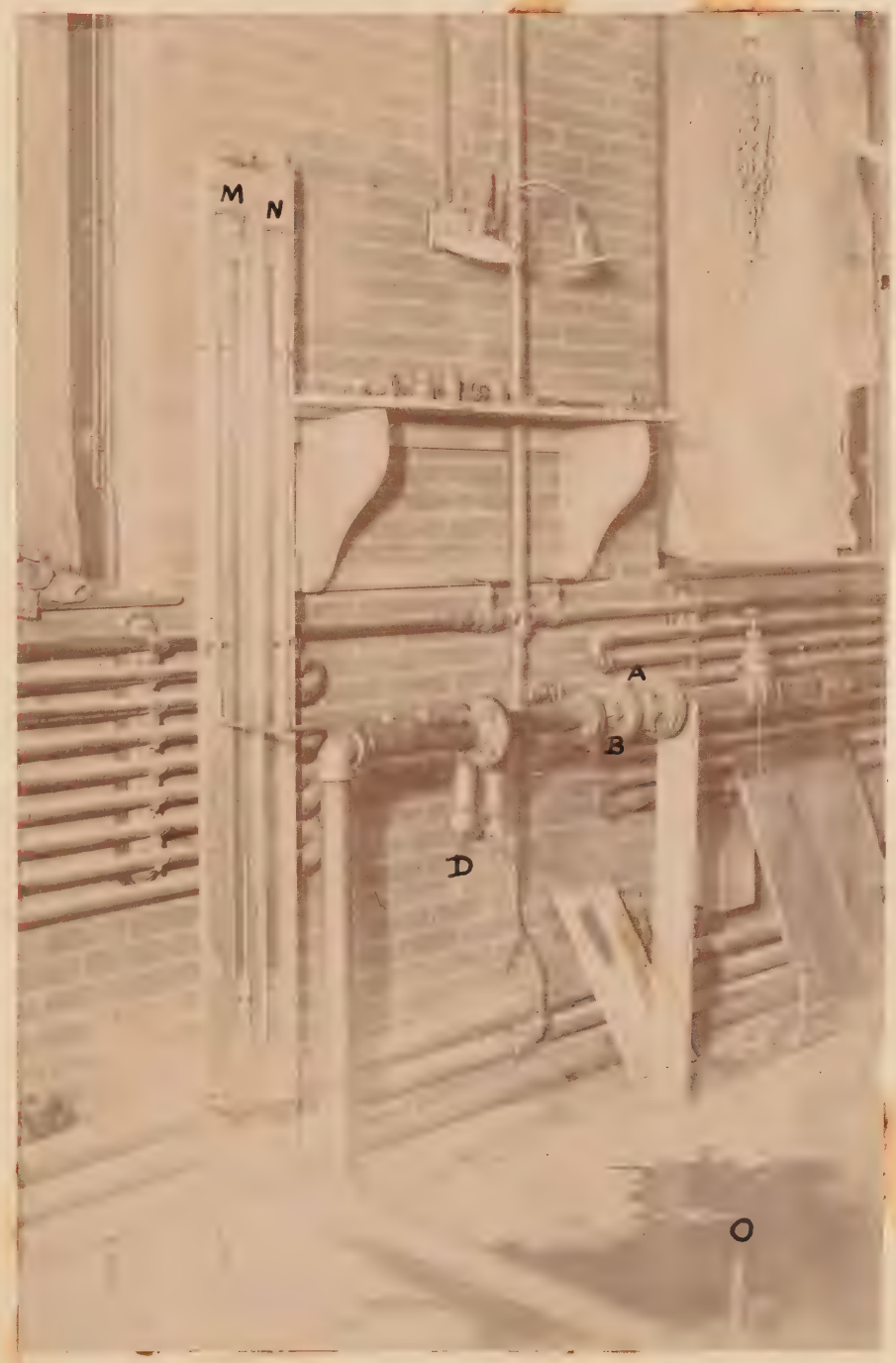


Figure 4.

A section of the pressure chamber A is shown in figure 5.

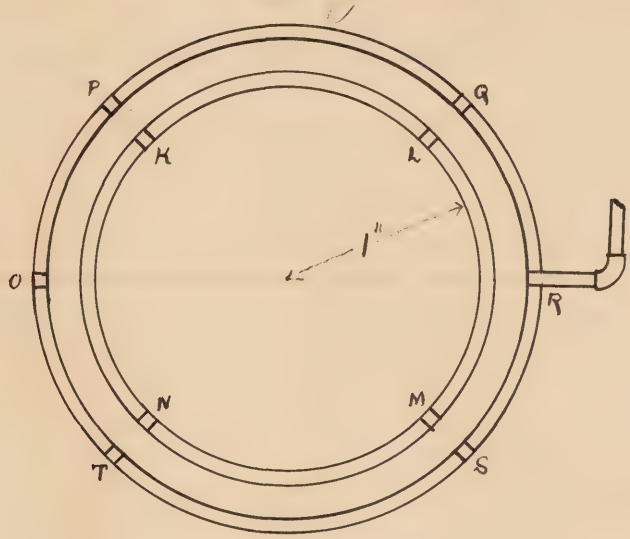


Figure 5.

The four small holes, about 1/16" in diameter, shown at K, L, M, and N open into the pressure chamber from which a pipe at R leads to the manometer MN shown in fig. 4. The five vents O, P, Q, S and T are closed by brass plugs and it will be noticed that no holes are opposite the two vents R and C

from which the manometer connections are made. This is to avoid the variations of pressure in the manometer tube which the pumping action of the flow is found to produce.

The main object of the series of experiments here recorded was the determination of the quantity of flow through the venturi meter under various conditions of head. The apparatus as used is shown in the photograph figure 4 The water used was supplied from a large tank in the third story of the engineering building. The approximate head of the tank on the meter was thirty feet. Regulation of

the quantity of flow was obtained by the valve O fig 4 beyond the down stream end of the meter so that the tube worked drowned an essential condition for its proper use. From the valve O the water discharged directly into the cistern beneath the building where the quantity was determined by hook gauge readings and the curve derived in experiment number one. From the vent R fig. 5 one eighth inch piping lead through the air chamber D and a three way cock, to the upper end of the manometer tube M fig. 4. A similar pipe from the throat pressure chamber lead through the second air chamber and a three way cock to the opposite

end N of the manometer. When the cocks were properly turned the manometer registered the difference in pressure between the upstream end of the meter and the throat or the quantity $(H_1 - H_2)$ in Herrman's formula for the discharge through a venturi

$$Q = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2g(H_1 - H_2)}$$

Any water which carried over during the experiment lodged in the air chambers and was discharged by opening the cock to the atmosphere

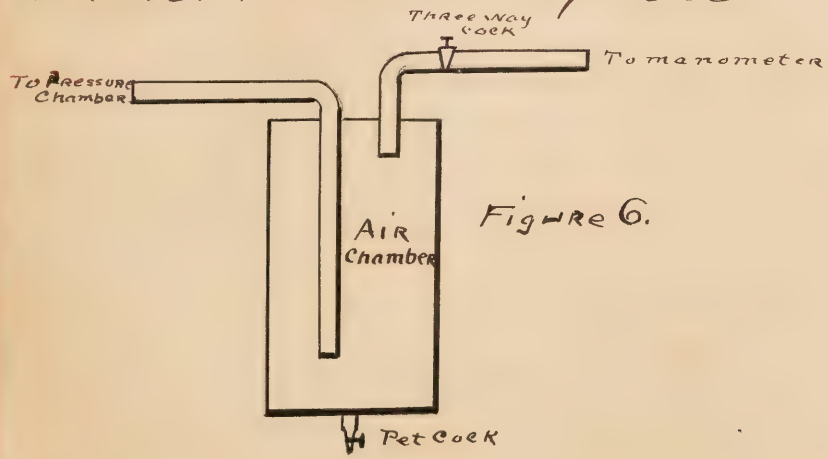


Figure 6.

Figure six shows the arrangement of the air

chamber and explains itself. The chamber was not large enough to hold all the water carried over in the experiments made with small heads some of the water carrying over beyond the air chamber and three way cock and necessitating the abandoning of three experiments viz 1, 10, and 11 in experiment 4. Experiment 1 is not reliable owing to the leakage of valves and the probability that water was in the pipes beyond the air chamber from the beginning of the experiment.

Experiment number 10 is unreliable for the reason that five minutes before the closing of the run water carried over and the pressure became so variable that the

run was stopped three minutes before the scheduled time. In experiment 11 the same thing happened ten minutes before the close.

Each of the runs lasted one half hour half minutes readings of the heights in the two branches of the manometer being recorded. The first reading was taken one half minute after the opening of the valve and the last one half minute before the closing of the run thus giving fifty nine readings. In computing the results the mean of each ten differences of pressure viz $(H_1 - H_2)$ see experiment four was taken excepting in the last reading where the number of observations necessitated taking the mean of

nine observations. The quantity of flow was deduced for each of these mean heads from the formula derived in experiment 3 viz;

$$Q = 75.218\sqrt{H_1 - H_2} \text{ cu ft per hour.}$$

The mean of the six Q's so determined was taken as the theoretical discharge. The actual discharge was determined from the hook-gauge readings taken at the beginning and end of the trial by means of the calibration curve appended. The value of c or coefficient of discharge was determined for each case by dividing the theoretical into the actual discharge. The values will be found in the table numbered 4. A detailed description of the experiments follows.

[illegible]

[illegible]

[illegible]

[illegible]

W_1 = weight of [illegible] the fuel.
W_2 = " " [illegible] water.
W = $W_1 - W_2$ = weight of water [illegible].
Q = number of cubic feet of water in the tank corresponding to the [illegible] reading
R = [illegible] reading.
W_T = weight of water in tank.

Table I

Date	W_1	W_2	W	R	W_T	Q
Feb 15, 1897	695.75	171.50	524.25	34.95		
	673.50	198.00	475.50			
	701.50	163.75	537.75			
	721.00	188.25	532.75	32.98	2070.25	33.18
	710.25	150.25	560.00			
	[illegible]	217.50	488.50	31.99	3118.20	49.98
	701.00	170.25	530.75			
	705.75	171.25	534.50	30.99	4183.50	67.04
	704.50	170.25	534.25			
	680.00	177.25	502.75	30.00	5220.50	83.66
	705.00	151.75	553.25			
	683.25	172.00	511.25	28.93	6280.50	[illegible]
	700.50	148.25	552.25			
	690.00	179.00	511.00	27.98	7348.25	117.76
Feb 19,	715.50	170.00	545.50	34.97		
	620.25	180.50	439.75	34.03	985.25	15.79
	667.75	163.25	504.50			
	672.50	181.50	491.00	33.08	1980.75	31.74
	659.50	163.50	496.00			
	635.00	166.00	469.00	32.18	2945.75	47.21
	684.50	168.75	515.75			
	660.00	210.00	450.00	31.24	3911.50	62.69
	677.25	169.25	508.00			
	652.25	170.00	482.25	30.31	4901.75	78.56
	686.25	166.25	520.00			
	673.75	163.00	510.75	29.33	5932.50	95.07
	[illegible]	159.75	[illegible]			
	671.50	150.25	[illegible]	28.34	6978.75	111.84
	667.50	162.75	504.75			
	677.25	218.25	459.00	27.42	7942.50	127.29
	669.75	154.25	515.50			
	698.00	149.00	549.00	26.43	9007.00	144.35
	668.00	168.75	499.25			
	670.50	173.25	497.25	25.47	10003.50	160.32
	672.75	168.50	[illegible]			
	670.00	159.75	510.25	24.51	11018.00	176.57
	694.50	156.25	538.25			
	693.25	167.00	526.25	23.49	12082.50	193.63
	669.75	150.00	519.75			
	698.50	148.50	550.00	22.47	13152.25	210.78
	713.25	162.00	551.25			
	698.50	155.00	543.50	21.44	14247.00	228.32
	670.12	171.50	498.62			
	682.50	170.00	512.50	20.48	15257.12	[illegible]
	672.00	169.25	502.75			
	664.00	160.75	503.25	19.56	16264.12	[illegible]
	678.00	169.40	508.60			
	[illegible]	171.25	[illegible]	18.64	[illegible]	[illegible]
	681.25	168.25	513.00			
	705.75	161.00	544.75	17.67	18346.22	294.01

Table I

Date	W_1	W_2	W	R	W_T	Q
	687.00	166.63	520.37	28.69		
Feb. 20.	676.00	148.75	527.25	27.68	1047.62	122.34
	656.25	169.50	486.75			
	674.25	171.00	503.25	26.75	2037.62	138.20
	684.50	165.00	519.50			
	687.25	170.25	517.00	25.75	3074.12	154.81
	681.50	159.50	522.00			
	682.50	156.50	526.00	24.73	4122.12	171.61
	677.50	158.00	519.50			
	687.00	147.25	539.75	23.72	5181.37	188.58
	675.75	159.25	516.50			
	679.00	161.75	517.25	22.74	6215.12	205.15
	684.75	157.25	527.50			
	677.50	146.75	530.75	21.78	7273.37	222.
	[illegible]	[illegible]	[illegible]			
	657.25	156.00	501.25	20.77	8288.62	238.40
	674.87	150.75	524.12			
	672.00	153.25	518.75	19.79	9331.49	255.09
	681.00	154.50	526.50			
	694.00	156.00	538.00	18.85	10395.99	272.15
	680.00	171.50	508.50			
	670.75	155.00	515.75	17.91	11420.24	288.57
	694.00	161.25	532.75			
	670.25	156.00	514.25	16.96	12467.24	305.35
	693.75	152.75	541.00			
	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	684.25	157.00	527.25			
	669.50	161.25	508.25	15.06	14545.99	338.64
	677.25	169.12	508.13			
	693.75	171.00	522.75	14.13	15576.87	355.12
	672.25	154.00	518.25			
	704.00	154.25	549.75	13.16	16644.87	372.30
	674.50	160.50	514.00			
	682.25	161.25	521.00	12.22	17679.87	388.88
	684.00	149.50	534.50			
	703.50	157.00	546.50	11.23	18760.87	406.21
	661.12	161.75	499.37			
	675.00	163.50	511.50	10.31	19771.74	422.41
	692.00	153.25	538.75			
	687.00	157.75	529.25	9.34	20839.74	439.52
	675.50	167.75	507.75			
	677.00	176.25	500.75	8.43	21848.24	455.69
	692.50	156.37	536.13			
	689.00	162.25	526.75	7.45	22911.12	472.72
	[illegible]	[illegible]	[illegible]			
	694.25	148.00	546.25	6.50	23981.12	489.87
	692.75	[illegible]	[illegible]			
	688.75	156.75	532.00	5.51	25052.87	507.05
	696.50	153.50	543.00			
	683.25	158.50	524.75	4.55	26120.62	524.16
	682.12	147.50	534.62			
	692.25	[illegible]	[illegible]	3.58	[illegible]	[illegible]
	674.00	164.00	510.00			
	682.75	157.00	[illegible]	2.65	28204.24	[illegible]

Table I

Date	W_1	W_2	W	R	W_T	Q
Feb. 20.	662.00	152.00	510.00			
	694.50	165.00	529.50	1.73	29243.74	574.21
	683.50	158.50	525.00			
	674.50	146.25	528.25	.77	30296.99	591.09
	726.00	153.50	572.50	.26		
	649.00	360.00	289.00	.40	31158.49	604.90
Feb. 22	670.25	171.00	499.25	19.32		
	644.75	165.00	479.75	18.45	979.00	280.69
	681.50	167.00	514.50			
	672.25	158.75	513.50	17.51	2007.00	297.16
	665.75	163.50	502.25			
	668.50	177.75	490.75	16.59	3000.00	313.02
	671.25	172.12	499.13			
	676.50	156.75	519.75	15.68	4018.88	329.41
	680.25	164.25	516.00			
	679.25	171.50	507.75	14.75	5042.63	345.81
	675.00	169.25	505.75			
	677.50	191.50	486.00	13.85	6034.38	361.71
	695.75	160.00	535.75			
	688.25	168.00	520.25	12.91	7090.38	378.63
	676.25	173.50	502.75			
	684.75	165.50	519.25	11.96	8112.38	395.01
	[illegible]	170.37	[illegible]			
	688.25	151.00	537.25	10.98	9169.26	411.95
	683.50	154.75	528.75			
	657.25	160.50	496.75	10.05	10194.76	428.39
	692.75	171.62	521.13			
	700.00	160.25	539.75	9.08	11255.64	445.38
	694.75	167.75	527.00			
	687.50	163.50	524.00	8.13	12306.64	463.22
	706.00	170.50	535.50			
	[illegible]	[illegible]	[illegible]	7.[illegible]	13357.89	479.[illegible]
	691.50	170.25	520.25			
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	692.00	168.00	524.00			
	683.50	174.50	509.00	5.33	15417.64	572.08
	697.00	168.00	529.00			
	695.00	154.75	540.25	4.32	16486.89	529.22
	705.50	171.50	534.00			
	688.75	162.50	526.25	3.36	17547.14	546.21
	692.00	168.62	523.38			
	696.25	151.00	545.25	2.42	18615.77	563.34
	702.00	171.00	531.00			
	683.50	158.75	524.75	1.45	19671.52	580.26
	705.75	171.25	534.50			
	691.75	157.25	534.50	.50	20740.52	597.39
	704.00	165.62	538.38	.02	21278.90	606.01

The method of computing the quantities in the column headed Q is simple, the weight of water in the tank being divided by the weight of one cubic foot of water. The cologarithm of the weight of one cubic foot of water viz. (9.204825) is derived in experiment number two.

The weight of water in the cistern after the first observation on February twenty-second (see table I) was 979 lbs

log 979	2.990783
colog 62.39	9.204825
	1.195608

cu feet = 15.689

The other calculations were made in similar manner. In order to make practical use of the results of this experiment it was necessary to plot a curve showing the relation

of inches of height on the hook gauge and cubic feet of water in the cistern. The curve will be found attached under the head "Calibration Curve of a Cistern in the Hydraulic Laboratory of the University of Pennsylvania." The ordinates of the curve are hook gauge readings and the abscissae cubic feet. The zero of the cistern was arbitrarily chosen as the 35" mark of the hook gauge. The curve starts at the lower left hand corner goes to the upper right hand corner then drops to the lower right hand corner and ends at the upper left hand corner. The left hand and lower number refer to the first branch of the curve and the right hand and upper numbers go with the second

section. A bulge in the curve will be noticed commencing at about the 19 inch reading of the gauge. This is due to a forebay joining the main cistern at this point. Owing to the unavoidable lodging of waste water and splashed water from the emptying of the tanks on a sill on the sloping bottom of this forebay the points at this section do not accurately fit the curve. This part of the curve was however not used in the subsequent observations on the venturi meter so does not in any way vitiate their accuracy.

The two sets of readings are marked by points thus ⊕, ○. In the second section of the curve it will be noticed that one set of these points is uniformly below the curve while

the other set are as uniformly above the curve. Owing to the length of time required for a complete calibration of the tank the work had to be done in two sections. As it was not possible to bring the level of water to the exact point of stopping in the previous days readings that portion of the curve already determined was used as a reference and the quantity of water in the tank at the beginning of the second half of each experiment was read from the curve developed by the first half. It is easy to see how a constant error as shown in the plotting of the points on the second half of the curve could creep in. The curve may however be relied on to the tenth of a cubic foot.

Experiment Number Two.

This series of observations was taken for the purpose of determining the exact weight of one cubic foot of the water used in the calibration of the cistern in experiment number one. The water used was drawn from the city mains and was in a muddy condition. A glass beaker with a narrow neck holding two hundred and fifty cubic centimeters when filled to a mark on the neck was filled from about every third tank full of water used in experiment one. This beaker of water was then accurately weighed to grains (apothecaries weight)
The weighing and subsequent calculations are given below.

Table 2.

Weight 250 c.c. Water

oz	drch.	scr.	gr.		gr gp.		lbs. Avd.
11	1	1	2	=	3857	=	.5511
11	1	1	0	=	3855	=	.5507
11	1	1	3	=	3858	=	.5511
11	1	1	1	=	3856	=	.5508
11	1	1	-1	=	3854	=	.5506
11	1	1	0	=	3855	=	.5507
11	1	1	0	=	3855	=	.5507
11	1	1	3	=	3858	=	.5511
11	1	1	1	=	3856	=	.5508
11	1	1	2	=	3857	=	.5510
11	1	1	3	=	3858	=	.5511
11	1	1	3	=	3858	=	.5511

Temperature of Water 65°F.
Weight of Beaker 1505 gr. apoth.
The constant weight of the beaker is subtracted from columns two and three.

log .5511 741262
054095
795357 — log X in 250cc = X cu ft
62.4247 x 4 = 249.6988

.551 741152
054095
795247 — 62.4089 x 2 = 124.8178

.5508 741041
054095
795136 — 62.3930 x 2 = 124.7860

.5507 740915
054095
795010 — 62.3734 x 3 = 187.1202

.5506 740812
054095
794907 — 62.3601 x 1 = 62.3601

12 | 748.7829
62.3986

Average weight of one cubic foot of water was 62.3986 lbs av.

colog 62.3986 = 9.204825
This colog was used in the computation under experiment one

There can be little doubt as to the accuracy and reliability of this determination of the specific gravity of the water used. The refinement of means used, and agreement of results with the generally accepted value of the specific gravity of water at the temperature of 65°F (see Kent's Engineers Hand book) give it the stamp of credibility.

Experiment number three.

The formula given by Herrman for the discharge through a Venturi meter viz. $Q = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2g(H_1 - H_2)}$ necessitates the determination of the values a_1 the area of the venturi at the up stream pressure chamber and a_2 the area of the tube at the throat or smallest section. In

order to accomplish this end the meter was removed from the piping and the readings of the diameters at these two points made with a pair of inside calipers and a steel scale reading to hundredths of an inch. The readings were as follows,

d_1	d_2
2.00	.66
2.00	.67
2.01	.67
2.00	.67
2.00	.67
2.00	.67
2.00	.67
2.00	.66
2.01	.67
2.00	.67
10 | 20.02	10 | 6.68
2.002	.668

$$a_1 = \frac{\pi d_1^2}{4(144)} = \frac{.7854\ (2.002)^2}{144} \text{ sq. ft.}$$

$$a_1 = .02186 \text{ sq. ft.}$$

$$\begin{array}{r} \bar{1}.8950909 \\ .6029282 \\ .8416375 \\ \hline \bar{2}.3396566 \end{array}$$

$$a_2 = \frac{\pi d_2^2}{4(144)} = \frac{.7854\ (.668)^2}{144} \text{ sq. ft.}$$

$$a_2 = .002434 \text{ sq. ft.}$$

$$\begin{array}{r} \bar{1}.8950909 \\ \bar{1}.6495530 \\ .8416375 \\ \hline \bar{3}.3862814 \end{array}$$

$(a_1 - a_2) = .01943$

$(a_1 + a_2) = .02429$ $\quad (a_1^2 - a_2^2) = .01943 \times .02429$

$$\sqrt{a_1^2 - a_2^2} = \sqrt{.01943 \times .02429}$$

$$\begin{array}{r} \bar{2}.2884728 \\ \bar{2}.3854275 \\ \hline \bar{4}.6739003 \\ \bar{2}.3369502 \end{array}$$

$$a_1 a_2 = .02186 \times .002434$$

$$\begin{array}{r} \bar{2}.3862814 \\ \bar{3}.3396566 \\ \hline \bar{5}.7259380 \end{array}$$

The readings $H_1 - H_2$ were taken on a mercury manometer hence the readings in inches of mercury multiplied by $\frac{13.58}{12} = \frac{\text{specific gravity of mercury}}{12 \text{ inches}}$ give the readings in feet of water hence

$$Q = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2g(H_1 - H_2)}$$

$$Q = \frac{\text{nolog } \bar{5}.7259380}{\text{nolog } \bar{2}.3369502} \sqrt{64.32} \sqrt{\frac{13.58}{12}} \sqrt{H_1 - H_2} \, (3600)$$

in which H_1 and H_2 are in inches of mercury and Q is in cubic feet per hour

$$\begin{array}{r} \bar{5}.7259380 \\ .9041730 \\ .5764499 \\ .6630498 \\ 8.4604091 \\ 3.5563025 \\ \hline 1.8763226 \end{array}$$

$$Q = 75.218 \sqrt{H_1 - H_2} \text{ cu ft per hr.}$$

The logarithm 1.8763226 is used in the subsequent calculations of the discharge in experiment four.

Experiment number four.

A detailed account of the method of conducting this experiment has already been given so further comment will be unnecessary. The quantities in the following table are

H_1 = reading of throat side of manometer

H_2 = " " upstream " " "

$H_1 - H_2$ = difference of first two columns

Q_1 = theoretical discharge computed from mean of ten pressure readings

Q = mean theoretical discharge

q = actual discharge from calibration curve

c = coefficient of discharge $= \frac{q}{Q}$

h = mean of ten $(H_1 - H_2)$ observations.

Table 4.

Time	H_1	H_2	H_1-H_2	h	Q_1
			1		
10.25					
	31.94	23.34	8.60		
	31.96	23.30	8.66		
	31.94	23.31	8.63		
	31.91	23.31	8.60		
	31.90	23.31	8.59		
	31.90	23.31	8.59		
	31.91	23.30	8.61		
	31.91	23.31	8.60		
	31.91	23.31	8.60		
10.30	31.90	23.30	8.60	8.608	220.71
	31.91	23.31	8.60		
	31.91	23.30	8.61		
	31.91	23.30	8.61		
	31.92	23.29	8.63		
	31.92	23.30	8.62		
	31.92	23.30	8.62		
	31.92	23.32	8.60		
	31.92	23.29	8.63		
	31.92	23.29	8.63		
10.35	31.93	23.28	8.65	8.620	220.84
	31.92	23.27	8.65		
	31.93	23.27	8.66		
	31.94	23.28	8.66		
	31.98	23.21	8.77		
	31.97	23.23	8.74		
	31.97	23.23	8.74		
	31.97	23.24	8.73		
	31.97	23.23	8.74		
10.40	31.96	23.24	8.72	8.715	222.99
	31.96	23.24	8.72		
	31.97	23.23	8.74		
	31.96	23.23	8.73		
	31.95	23.23	8.72		
	31.96	23.23	8.73		
	31.96	23.23	8.73		
	31.96	23.24	8.72		
	31.97	23.24	8.73		
	31.95	23.23	8.72		
10.45	31.95	23.25	8.70	8.724	222.12
	31.96	23.24	8.72		
	31.95	23.24	8.71		
	31.96	23.24	8.72		
	31.96	23.24	8.72		
	31.95	23.24	8.71		
	31.96	23.24	8.72		
	31.95	23.24	8.71		
	31.96	23.25	8.71		
	31.95	23.25	8.70		
10.50	31.95	23.25	8.70	8.722	222.12
	31.95	23.24	8.71		
	31.94	23.26	8.68		
	31.94	23.26	8.68		
	31.95	23.26	8.69		
	31.94	23.27	8.67		
	31.95	23.26	8.69		
	31.95	23.27	8.68		
	31.94	23.27	8.67		
10.55	31.95	23.27	8.68	8.69	221.73
gauge	10.55	23.49	$g = 197.4$		
	10.25	29.33	$Q = 221.6$	$c = .8907$	

Time	H_1	H_2	H_1-H_2	h	Q_1
			2.		
11.00					
	32.66	22.51	10.15		
	32.62	22.53	10.09		
	32.62	22.54	10.08		
	32.61	23.53	10.08		
	32.63	22.51	10.12		
	32.64	22.49	10.15		
	32.66	22.48	10.18		
	32.67	22.45	10.22		
	32.68	22.45	10.23		
11.05	32.68	22.44	10.24	10.154	239.69
	32.68	22.45	10.23		
	32.67	22.44	10.23		
	32.67	22.44	10.23		
	32.67	22.44	10.23		
	32.66	22.44	10.22		
	32.67	22.43	10.24		
	32.66	22.45	10.21		
	32.66	22.43	10.23		
	32.66	22.44	10.22		
11.10	32.66	22.43	10.23	10.227	240.54
	32.65	22.45	10.20		
	32.65	22.45	10.20		
	32.65	22.46	10.19		
	32.65	22.46	10.19		
	32.65	22.47	10.18		
	32.64	22.47	10.17		
	32.64	22.47	10.17		
	32.64	22.47	10.17		
11.15	32.65	22.47	10.18	10.183	240.03
	32.64	22.46	10.18		
	32.64	22.47	10.17		
	32.64	22.47	10.17		
	32.64	22.48	10.16		
	32.65	22.47	10.18		
	32.64	22.48	10.18		
	32.63	22.47	10.16		
	32.63	22.48	10.15		
	32.63	22.48	10.15		
11.20	32.63	22.48	10.15	10.163	239.79
	32.64	22.48	10.16		
	32.64	22.47	10.17		
	32.63	22.48	10.15		
	32.65	22.46	10.19		
	32.63	22.49	10.14		
	32.63	22.48	10.15		
	32.63	22.48	10.15		
	32.63	22.48	10.15		
	32.63	22.47	10.16		
11.25	32.63	22.47	10.16	10.158	239.73
	32.63	22.48	10.15		
	32.64	22.47	10.17		
	32.63	22.48	10.15		
	32.63	22.48	10.15		
	32.63	22.48	10.15		
	32.63	22.48	10.15		
	32.65	22.47	10.18		
	32.64	22.47	10.17		
11.30	32.63	22.48	10.15	10.150	239.64
gauge	11.00	23.49	30.76		
	11.30	16.84	193.4		
			114.2		
			2		
			228.4		
$g = 228.4$					
$Q = 239.9$			$c = .952$		

Time	H_1	H_2	H_1-H_2	h	Q_1'
11.40		3			
	33.73	21.21	12.52		
	33.69	21.23	12.46		
	33.70	21.21	12.49		
	33.71	21.19	12.52		
	33.72	21.18	12.54		
	33.72	21.17	12.55		
	33.72	21.17	12.55		
	33.72	21.18	12.54		
	33.72	21.16	12.56		
11.45	33.72	21.16	12.56	12.529	266.25
	33.73	21.14	12.59		
	33.72	21.16	12.56		
	33.70	21.18	12.52		
	33.72	21.16	12.56		
	33.71	21.19	12.52		
	33.71	21.18	12.53		
	33.71	21.17	12.54		
	33.71	21.18	12.53		
	33.72	21.16	12.56		
11.50	33.72	21.15	12.57	12.548	266.45
	33.72	21.15	12.57		
	33.72	21.14	12.58		
	33.73	21.15	12.58		
	33.73	21.13	12.60		
	33.72	21.15	12.57		
	33.72	21.15	12.57		
	33.71	21.16	12.55		
	33.72	21.16	12.56		
	33.71	21.16	12.55		
11.55	33.71	21.16	12.55	12.568	266.66
	33.71	21.14	12.57		
	33.71	21.16	12.55		
	33.71	21.16	12.55		
	33.70	21.16	12.54		
	33.71	21.16	12.55		
	33.72	21.15	12.57		
	33.71	21.19	12.52		
	33.71	21.16	12.55		
	33.70	21.16	12.54		
12.00	33.72	21.16	12.56	12.552	266.49
	33.71	21.17	12.54		
	33.71	21.17	12.54		
	33.71	21.16	12.55		
	33.71	21.17	12.54		
	33.70	21.16	12.54		
	33.70	21.17	12.53		
	33.70	21.16	12.54		
	33.70	21.17	12.53		
	33.71	21.16	12.55		
12.05	33.71	21.16	12.55	12.541	266.37
	33.71	21.17	12.54		
	33.71	21.18	12.53		
	33.72	21.17	12.55		
	33.71	21.18	12.53		
	33.70	21.18	12.52		
	33.70	21.17	12.53		
	33.71	21.18	12.53		
	33.70	21.18	12.52		
12.10	33.70	21.18	12.52	12.530	266.26
	gauge	11.40 —	16.63 —	3144	
		12.10 —	9.37 —	439.7	
				128.3 / 2	
				2566	
	$g =$	256.6			
	$Q =$	266.4	$c =$	.963	

Time	H_1	H_2	H_1-H_2	h	Q_1
1.32		4			
	35.36	19.15	16.21		
	35.36	19.12	16.24		
	35.38	19.10	16.28		
	35.37	19.10	16.27		
	35.37	19.08	16.29		
	35.38	19.12	16.26		
	35.38	19.09	16.29		
	35.35	19.10	16.25		
	35.35	19.10	16.25		
1.37	35.35	19.10	16.25	16.259	303.30
	35.36	19.09	16.27		
	35.36	19.12	16.24		
	35.36	19.09	16.27		
	35.35	19.10	16.25		
	35.34	19.11	16.23		
	35.34	19.10	16.24		
	35.34	19.11	16.23		
	35.33	19.12	16.21		
	35.33	19.11	16.22		
1.42	35.35	19.11	16.24	16.240	303.12
	35.35	19.09	16.26		
	35.33	19.12	16.21		
	35.36	19.08	16.28		
	35.34	19.09	16.25		
	35.36	19.11	16.25		
	35.35	19.10	16.25		
	35.33	19.09	16.24		
	35.33	19.09	16.24		
	35.34	19.10	16.24		
1.47	35.34	19.10	16.24	16.246	303.18
	35.33	19.09	16.23		
	35.34	19.10	16.24		
	35.34	19.10	16.24		
	35.33	19.10	16.23		
	35.33	19.09	16.24		
	35.33	19.10	16.23		
	35.33	19.10	16.23		
	35.33	19.10	16.23		
	35.34	19.10	16.24		
1.52	35.33	19.10	16.23	16.234	303.07
	35.32	19.11	16.21		
	35.34	19.11	16.23		
	35.32	19.11	16.21		
	35.32	19.11	16.21		
	35.33	19.11	16.22		
	35.33	19.11	16.22		
	35.32	19.11	16.21		
	35.33	19.11	16.22		
	35.32	19.11	16.21		
1.57	35.33	19.11	16.22	16.216	302.96
	35.32	19.11	16.21		
	35.32	19.12	16.20		
	35.32	19.12	16.20		
	35.32	19.12	16.20		
	35.33	19.11	16.22		
	35.32	19.11	16.21		
	35.33	19.10	16.23		
	35.32	19.11	16.21		
	35.32	19.11	16.21	16.210	302.84
2.02					
	gauge	1.32	31.92	50.8	
		2.02	23.21	198.	
				147.2 / 2	
				294.4	
	$g =$	294.4			
	$Q =$	303.07	$c =$	.971	

Time	H_1	H_2	H_1-H_2	π	Q_1
2.14		5			
	35.98	18.41	17.57		
	36.97	18.38	17.59		
	35.98	18.32	17.66		
	35.96	18.33	17.63		
	36.96	18.32	17.64		
	35.98	18.38	17.60		
	35.94	18.38	17.56		
	36.95	18.32	17.63		
	35.94	18.38	17.56		
	35.92	18.40	17.52	17.596	315.52
	35.89	18.41	17.48		
	35.88	18.42	17.46		
	35.88	18.42	17.46		
	36.88	18.43	17.45		
	35.89	18.40	17.49		
	35.87	18.43	17.44		
	35.87	18.42	17.45		
	35.87	18.43	17.44		
	35.88	18.43	17.45		
	35.87	18.44	17.43	17.455	314.26
	35.88	18.44	17.44		
	35.88	18.42	17.46		
	35.88	18.44	17.44		
	35.86	18.43	17.43		
	36.88	18.42	17.46		
	36.89	18.43	17.46		
	36.87	18.44	17.43		
	35.87	18.42	17.45		
	35.87	18.44	17.43		
	35.88	18.45	17.43	17.443	314.15
	35.87	18.42	17.45		
	35.87	18.42	17.45		
	35.88	18.43	17.45		
	35.88	18.42	17.46		
	35.89	18.42	17.47		
	35.85	18.40	17.45		
	35.87	18.43	17.44		
	35.88	18.42	17.46		
	36.86	18.43	17.43		
	35.86	18.44	17.42	17.448	314.19
	35.85	18.45	17.40		
	35.86	18.45	17.41		
	36.87	18.46	17.41		
	36.86	18.45	17.41		
	35.85	18.46	17.39		
	35.86	18.44	17.42		
	35.86	18.44	17.42		
	35.86	18.45	17.41		
	36.84	18.46	17.38		
	35.85	18.45	17.40	17.405	313.80
	35.84	18.47	17.37		
	35.84	18.47	17.37		
	35.85	18.46	17.39		
	35.83	18.47	17.36		
	35.85	18.46	17.39		
	35.87	18.47	17.40		
	35.86	18.46	17.40		
	35.85	18.47	17.38		
	35.84	18.47	17.37	17.381	313.59
	gauge	14.16	355.6		
		23.01	201.4		
			154.2		
			2		
			308.4		
	$q =$	308.4			
	$Q =$	314.25	$c = .981$		

Time	H_1	H_2	H_1-H_2	π	Q_1
3.27		6			
	36.74	17.45	19.29		
	36.76	17.38	19.38		
	36.75	17.35	19.40		
	36.75	17.38	19.37		
	36.76	17.34	19.42		
	36.75	17.35	19.40		
	36.75	17.35	19.40		
	36.76	17.34	19.42		
	36.75	17.34	19.41		
	36.76	17.34	19.42	19.391	331.23
	36.76	17.34	19.42		
	36.75	17.35	19.40		
	36.75	17.36	19.39		
	36.74	17.38	19.36		
	36.73	17.34	19.39		
	36.74	17.34	19.40		
	36.74	17.36	19.38		
	36.76	17.38	19.38		
	36.74	17.35	19.39		
	36.73	17.35	19.38	19.389	331.21
	36.73	17.37	19.36		
	36.75	17.33	19.42		
	36.74	17.37	19.37		
	36.72	17.33	19.39		
	36.75	17.36	19.39		
	36.75	17.35	19.40		
	36.73	17.37	19.36		
	36.74	17.38	19.36		
	36.73	17.37	19.36		
	36.73	17.37	19.36	19.377	331.10
	36.73	17.38	19.35		
	36.74	17.38	19.36		
	36.73	17.39	19.34		
	36.74	17.38	19.36		
	36.73	17.38	19.35		
	36.73	17.38	19.35		
	36.73	17.38	19.35		
	36.73	17.38	19.35		
	36.73	17.38	19.35		
	36.72	17.39	19.33	19.349	330.87
	36.71	17.40	19.31		
	36.72	17.39	19.33		
	36.71	17.40	19.31		
	36.70	17.41	19.29		
	36.73	17.40	19.33		
	36.70	17.40	19.30		
	36.68	17.42	19.26		
	36.70	17.39	19.31		
	36.68	17.42	19.26		
	36.70	17.40	19.30	19.300	330.45
	36.70	17.40	19.30		
	36.70	17.39	19.31		
	36.70	17.41	19.29		
	36.70	17.40	19.30		
	36.69	17.41	19.28		
	36.68	17.42	19.26		
	36.70	17.40	19.30		
	36.69	17.42	19.27		
	36.68	17.43	19.25	19.284	330.31
	gauge	17.76	296.2		
		27.16	137.5		
			158.7		
			2		
			317.4		
	$q =$	317.4			
	Q	330.8	$c = .981$		

Time	H_1	H_2	$H_1 - H_2$	T_1	Q_1
4.04	38.25	7. 15.52	22.73		
	38.25	15.49	22.76		
	38.26	15.48	22.78		
	38.25	15.49	22.76		
	38.26	15.48	22.78		
	38.24	15.47	22.77		
	38.23	15.48	22.75		
	38.23	15.48	22.75		
	38.22	15.49	22.73		
	38.22	15.48	22.74	22.755	358.81
	38.21	15.50	22.71		
	38.20	15.51	22.69		
	38.20	15.52	22.68		
	38.19	15.53	22.66		
	38.19	15.53	22.66		
	38.18	15.53	22.65		
	38.18	15.53	22.65		
	38.18	15.52	22.67		
	38.18	15.52	22.66		
	38.19	15.53	22.66	22.664	358.13
	38.19	15.53	22.66		
	38.18	15.54	22.64		
	38.15	15.58	22.57		
	38.18	15.53	22.65		
	38.17	15.55	22.62		
	38.17	15.53	22.62		
	38.16	15.57	22.59		
	38.18	15.58	22.60		
	38.16	15.55	22.61		
	38.18	15.53	22.63	22.617	357.72
	38.16	15.58	22.58		
	38.15	15.55	22.60		
	38.15	15.55	22.60		
	38.16	15.55	22.61		
	38.16	15.57	22.59		
	38.13	15.52	22.61		
	38.14	15.59	22.55		
	38.14	15.58	22.56		
	38.14	15.58	22.56		
	38.15	15.59	22.56	22.582	357.44
	38.16	15.58	22.58		
	38.15	15.60	22.55		
	38.15	15.59	22.56		
	38.12	15.55	22.57		
	38.18	15.60	22.58		
	38.14	15.60	22.54		
	38.12	15.52	22.60		
	38.17	15.55	22.62		
	38.15	15.58	22.57		
	38.15	15.55	22.60	22.577	357.40
	38.12	15.62	22.50		
	38.13	15.63	22.50		
	38.13	15.63	22.50		
	38.10	15.62	22.48		
	38.10	15.65	22.45		
	38.11	15.65	22.46		
	38.10	15.65	22.45		
	38.10	15.65	22.45		
	38.11	15.64	22.47	22.473	356.58

gauge 7.89 465.7
17.76 290.2
175.5
2
351.

$g = 351$

$Q = 357.68$ $c = .981$

Time	H_1	H_2	$H_1 - H_2$	T_2	Q_1
9.47	29.95	8 25.75	4.20		
	29.90	25.82	4.08		
	29.90	25.82	4.08		
	29.92	25.57	4.13		
	29.95	25.72	4.23		
	29.98	25.70	4.28		
	29.97	25.69	4.28		
	29.97	25.68	4.29		
	29.97	25.70	4.27		
	29.97	25.72	4.23	4.207	153.92
	29.95	25.72	4.23		
	29.94	25.72	4.22		
	29.94	25.72	4.22		
	29.94	25.72	4.22		
	29.93	25.72	4.21		
	29.93	25.73	4.20		
	29.94	25.72	4.22		
	29.93	25.72	4.21		
	29.93	25.71	4.22		
	29.93	25.72	4.21	4.216	154.45
	29.95	25.69	4.26		
	29.96	25.70	4.26		
	29.95	25.70	4.25		
	29.94	25.70	4.24		
	29.95	25.69	4.26		
	29.94	25.69	4.25		
	29.95	25.70	4.25		
	29.94	25.69	4.25		
	29.95	25.68	4.27		
	29.94	25.69	4.25	4.254	155.74
	29.94	25.70	4.24		
	29.93	25.65	4.25		
	29.94	25.69	4.25		
	29.95	25.69	4.26		
	29.94	25.70	4.24		
	29.94	25.69	4.25		
	29.94	25.68	4.26		
	29.94	25.68	4.25		
	29.94	25.69	4.25		
	29.95	25.68	4.27	4.252	155.10
	29.94	25.69	4.25		
	29.94	25.68	4.26		
	29.93	25.68	4.25		
	29.94	25.69	4.25		
	29.94	25.69	4.25		
	29.94	25.68	4.26		
	29.94	25.69	4.25		
	29.94	25.69	4.25		
	29.94	25.69	4.25		
	29.94	25.69	4.25	4.252	155.10
	29.94	25.69	4.25		
	29.94	25.70	4.24		
	29.94	25.70	4.24		
	29.94	25.70	4.24		
	29.94	25.70	4.24		
	29.93	25.71	4.22		
	29.94	25.70	4.24		
	29.94	25.70	4.24		
	29.93	25.69	4.24	4.239	154.87

gauge 9.13 443.8
13.33 370.3
73.5
2
147.

$g = 147$

$Q = 154.76$ $c = .950$

Time	H_1	H_2	$H_1 - H_2$	$\bar{h}$	Q.
10.21	29.39	26.49	2.90		
	29.34	26.48	2.86		
	29.34	26.49	2.85		
	29.33	26.48	2.85		
	29.33	26.48	2.85		
	29.35	26.47	2.88		
	29.33	26.45	2.88		
	29.35	26.45	2.90		
	29.34	26.46	2.88		
10.26	29.34	26.46	2.88	2.873	127.5
	29.33	26.46	2.87		
	29.34	26.45	2.89		
	29.34	26.46	2.88		
	29.34	26.46	2.88		
	29.34	26.44	2.90		
	29.34	26.45	2.89		
	29.34	26.45	2.89		
	29.34	26.44	2.90		
	29.34	26.44	2.90		
10.31	29.34	26.44	2.90	2.890	127.87
	29.36	26.42	2.94		
	29.35	26.43	2.92		
	29.36	26.42	2.94		
	29.36	26.44	2.92		
	29.36	26.43	2.93		
	29.35	26.43	2.92		
	29.36	26.43	2.93		
	29.36	26.42	2.94		
	29.36	26.42	2.94		
10.36	29.36	26.42	2.94	2.932	128.80
	29.36	26.42	2.94		
	29.37	26.42	2.95		
	29.35	26.42	2.93		
	29.36	26.42	2.94		
	29.36	26.43	2.93		
	29.36	26.42	2.94		
	29.36	26.44	2.92		
	29.35	26.43	2.92		
	29.35	26.43	2.92		
10.41	29.35	26.43	2.92	2.931	128.80
	29.36	26.45	2.91		
	29.34	26.43	2.91		
	29.34	26.43	2.91		
	29.34	26.43	2.91		
	29.36	26.43	2.92		
	29.34	26.43	2.91		
	29.35	26.43	2.92		
	29.34	26.43	2.91		
	29.34	26.43	2.91		
10.46	29.34	26.43	2.91	2.912	128.36
	29.34	26.42	2.92		
	29.34	26.43	2.91		
	29.34	26.42	2.92		
	29.34	26.43	2.91		
	29.34	26.43	2.91		
	29.34	26.43	2.91		
	29.34	26.42	2.92		
	29.34	26.43	2.91		
10.51	29.34	26.42	2.92	2.914	128.4

gauge 5.70 50.48
9.13 44.3.8
6 | 2
122.0

q = 122
Q = 128.29
c = .951

Time	H_1	H_2	$H_1 - H_2$	$\bar{h}$	Q.
10.59	28.88	27.08	1.80		
	28.87	27.07	1.80		
	28.86	27.07	1.79		
	28.87	27.05	1.82		
	28.86	27.04	1.82		
	28.87	27.05	1.82		
	28.86	27.04	1.82		
	28.86	27.03	1.83		
	28.86	27.03	1.83		
	28.86	27.04	1.82	1.815	101.34
	28.86	27.04	1.82		
	28.86	27.04	1.82		
	28.85	27.03	1.82		
	28.86	27.03	1.83		
	28.85	27.03	1.82		
	28.85	27.03	1.82		
	28.85	27.03	1.82		
	28.84	27.02	1.82		
	28.84	27.02	1.82		
	28.84	27.02	1.82	1.821	101.50
	28.85	27.02	1.83		
	28.84	27.02	1.82		
	28.84	27.01	1.83		
	28.84	27.01	1.83		
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.85	27.01	1.84	1.835	101.89
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.85	27.01	1.84		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.85	27.01	1.84	1.846	102.20
	28.85	27.01	1.84		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.86	27.02	1.83		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.86	27.01	1.85		
	28.85	27.01	1.84	1.846	102.20
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.85	27.01	1.84		
	28.89	27.01	1.88		
	28.92	26.91	2.01		
	28.93	26.90	2.03		
	28.93	26.90	2.03		
	28.93	26.90	2.03	1.92.7	104.41

gauge 2.96 55.3.2
5.70 52.4.8
4.8.4
2
96.8

q = 96.8
q = 102.26
c = .945

Time	H_1	H_2	H_1-H_2	h	Q₁
11.37		16			
	28.39	27.62	.77		
	28.39	27.62	.77		
	28.38	27.62	.78		
	28.39	27.62	.77		
	28.39	27.62	.77		
	28.38	27.62	.77		
	28.38	27.62	.76		
	28.38	27.62	.76		
	28.38	27.62	.76		
	28.37	27.61	.76		
	28.38	27.62	.76	.766	65.832
	28.38	27.62	.76		
	28.38	27.61	.77		
	28.38	27.61	.77		
	28.38	27.61	.77		
	28.38	27.61	.77		
	28.37	27.60	.77		
	28.37	27.60	.77		
	28.37	27.60	.77		
	28.37	27.60	.77		
	28.37	27.60	.77	.769	65.961
	28.38	27.60	.78		
	28.38	27.60	.78		
	28.37	27.60	.77		
	28.37	27.60	.77		
	28.37	27.60	.77		
	28.38	27.60	.78		
	28.38	27.60	.78		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79	.780	66.431
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79		
	28.38	27.59	.79	.790	66.855

gauge 1.34 581.8
2.96 583.2
28.6

g = 63.65
Q = 66.27 c = .969

Time	H_1	H_2	H_1-H_2	h	Q₁
9.34		12			
	39.50	13.80	25.70		
	39.55	13.80	25.75		
	39.55	13.79	25.76		
	39.55	13.80	25.75		
	39.58	13.78	25.80		
	39.54	13.78	25.76		
	39.55	13.77	25.78		
	39.54	13.78	25.76		
	39.55	13.78	25.77		
	39.57	13.79	25.78	25.761	381.76
	39.54	13.79	25.75		
	39.54	13.80	25.74		
	39.52	13.79	25.73		
	39.53	13.80	25.73		
	39.52	13.76	25.74		
	39.53	13.78	25.75		
	39.52	13.78	25.74		
	39.53	13.80	25.73		
	39.53	13.80	25.73		
	39.52	13.79	25.73	25.739	381.62
	39.55	13.78	25.75		
	39.52	13.80	25.72		
	39.53	13.81	25.72		
	39.54	13.82	25.72		
	39.53	13.82	25.71		
	39.55	13.81	25.70		
	39.55	13.83	25.72		
	39.54	13.82	25.74		
	39.54	13.79	25.75		
	39.53	13.80	25.73	25.726	381.54
	39.49	13.81	25.68		
	39.49	13.82	25.67		
	39.53	13.82	25.71		
	39.52	13.83	25.69		
	39.49	13.84	25.65		
	39.50	13.83	25.67		
	39.52	13.85	25.67		
	39.49	13.86	25.63		
	39.49	13.85	25.64		
	39.50	13.85	25.65	25.666	381.10
	39.48	13.87	25.61		
	39.49	13.86	25.63		
	39.49	13.85	25.64		
	39.48	13.88	25.60		
	39.48	13.87	25.61		
	39.50	13.89	25.61		
	39.48	13.87	25.61		
	39.48	13.89	25.59		
	39.47	13.90	25.57		
	39.47	13.90	25.57	25.604	380.58
	39.47	13.90	25.57		
	39.47	13.90	25.57		
	39.45	13.92	25.53		
	39.47	13.93	25.54		
	39.45	13.94	25.51		
	39.45	13.91	25.54		
	39.45	13.92	25.53		
	39.44	13.93	25.51		
	39.44	13.94	25.50	25.530	380.06

gauge 22.85 24.4
33.85 19.36
184.70
2
369.4

g = 369.4
Q = 381.11 c = .969

Time	H_1	H_2	H_1-H_2	H	Q,
10.13		13.			
	40.80	12.20	28.60		
	40.81	12.18	28.63		
	40.82	12.18	28.64		
	40.83	12.18	28.65		
	40.82	12.17	28.65		
	40.80	12.18	28.62		
	40.82	12.21	28.61		
	40.82	12.19	28.63		
	40.80	12.20	28.60		
	40.78	12.24	28.54	28.617	402.4
	40.78	12.21	28.57		
	40.78	12.23	28.55		
	40.78	12.22	28.56		
	40.80	12.22	28.58		
	40.75	12.23	28.52		
	40.75	12.24	28.57		
	40.75	12.26	28.49		
	40.75	12.26	28.49		
	40.75	12.24	28.51		
	40.75	12.28	28.47	28.585	402.19
	40.75	12.28	28.47		
	40.73	12.30	28.43		
	40.71	12.30	28.41		
	40.73	12.31	28.42		
	40.70	12.32	28.38		
	40.70	12.32	28.38		
	40.71	12.33	28.38		
	40.70	12.33	28.37		
	40.71	12.33	28.38		
	40.70	12.33	28.37	28.399	400.85
	40.68	12.35	28.33		
	40.69	12.34	28.35		
	40.68	12.35	28.33		
	40.67	12.32	28.31		
	40.68	12.36	28.32		
	40.67	12.36	28.31		
	40.68	12.35	28.33		
	40.68	12.37	28.31		
	40.66	12.37	28.29		
	40.67	12.38	28.29	28.317	400.29
	40.65	12.39	28.26		
	40.66	12.40	28.26		
	40.65	12.40	28.25		
	40.63	12.42	28.21		
	40.62	12.43	28.19		
	40.62	12.42	28.20		
	40.62	12.41	28.21		
	40.61	12.44	28.17		
	40.62	12.43	28.19		
	40.62	12.45	28.17	28.211	399.57
	40.62	12.43	28.19		
	40.62	12.45	28.17		
	40.62	12.44	28.18		
	40.61	12.46	28.15		
	40.60	12.47	28.13		
	40.61	12.46	28.15		
	40.58	12.47	28.11		
	40.59	12.47	28.12		
	40.57	12.46	28.11	28.15	399.08

gauge 11.67 399.50
29.85 204.0
195.5
2
391.0

g = 391
Q = 400.72 c = .976

Time	H_1	H_2	H_1-H_2	H	Q,
11.08		(14.			
	42.28	10.30	31.98		
	42.28	10.30	31.98		
	42.20	10.30	31.90		
	42.21	10.32	31.89		
	42.20	10.38	31.82		
	42.18	10.48	31.70		
	42.10	10.55	31.55		
	42.10	10.55	31.55		
	42.08	10.60	31.48		
11.13	42.95	10.63	31.32	31.717	453.63
	42.00	10.62	31.38		
	42.00	10.65	31.35		
	41.98	10.68	31.30		
	41.98	10.70	31.28		
	41.92	10.62	31.30		
	41.98	10.68	31.30		
	41.90	10.70	31.20		
	41.90	10.70	31.20		
	41.90	10.71	31.19		
11.18	41.90	10.70	31.20	31.270	420.64
	41.90	10.71	31.19		
	41.90	10.70	31.20		
	41.91	10.71	31.20		
	41.91	10.71	31.20		
	41.88	10.70	31.18		
	41.88	10.72	31.16		
	41.88	10.72	31.16		
	41.87	10.73	31.14		
	41.88	10.74	31.14		
	41.90	10.72	31.18	31.177	420.01
	41.88	10.75	31.13		
	41.86	10.76	31.10		
	41.86	10.75	31.11		
	41.85	10.78	31.07		
	41.84	10.80	31.04		
	41.84	10.80	31.04		
	41.84	10.82	31.02		
	41.85	10.82	31.03		
	41.84	10.80	31.04		
	41.84	10.83	31.01	31.059	419.20
	41.84	10.79	31.05		
	41.85	10.82	31.03		
	41.82	10.84	30.98		
	41.84	10.83	31.01		
	41.83	10.84	30.99		
	41.83	10.84	30.99		
	41.83	10.80	31.03		
	41.80	10.88	30.92		
	41.80	10.85	30.95		
	41.80	10.85	30.95		
	41.82	10.85	30.97	30.990	418.73
	41.81	10.85	30.96		
	41.80	10.85	30.95		
	41.80	10.90	30.90		
	41.80	10.90	30.90		
	41.79	10.91	30.88		
	41.79	10.92	30.87		
	41.79	10.92	30.87		
	41.79	10.91	30.88	30.91	418.19

gauge 8.19 460.5
19.93 253.4
207.1
2
414.2

g = 414.2
Q = 420.07 c = .985

Time	H_1	H_2	$H_1 - H_2$	h	Q_1
12.42		15			
	42.20	10.38	31.82		
	42.20	10.36	31.84		
	42.20	10.40	31.80		
	42.18	10.41	31.77		
	42.17	10.41	31.76		
	42.17	10.40	31.77		
	42.16	10.40	31.76		
	42.16	10.40	31.76		
	42.15	10.42	31.73		
	42.16	10.41	31.75	31.776	424.03
	42.16	10.42	31.74		
	42.15	10.43	31.72		
	42.15	10.42	31.71		
	42.15	10.42	31.73		
	42.12	10.43	31.76		
	42.12	10.47	31.65		
	42.12	10.48	31.64		
	42.10	10.50	31.60		
	42.11	10.48	31.63		
	42.10	10.50	31.60	31.669	423.30
	42.10	10.50	31.60		
	42.10	10.48	31.62		
	42.09	10.51	31.58		
	42.09	10.50	31.59		
	42.08	10.51	31.57		
	42.08	10.52	31.56		
	42.08	10.53	31.55		
	42.06	10.53	31.53		
	42.07	10.52	31.55		
	42.06	10.53	31.53	31.568	422.63
	42.05	10.53	31.52		
	42.03	10.52	31.49		
	42.03	10.52	31.57		
	42.03	10.50	31.55		
	42.02	10.55	31.47		
	42.02	10.56	31.46		
	42.02	10.54	31.48		
	42.00	10.57	31.43		
	42.02	10.57	31.45		
	42.00	10.57	31.44	31.480	422.03
	42.00	10.58	31.42		
	41.99	10.58	31.41		
	41.99	10.59	31.40		
	41.99	10.60	31.39		
	42.00	10.62	31.38		
	41.99	10.60	31.39		
	41.98	10.61	31.37		
	41.98	10.63	31.35		
	41.97	10.64	31.33		
	41.98	10.62	31.36	31.360	421.35
	41.98	10.63	31.35		
	41.98	10.63	31.35		
	41.97	10.65	31.32		
	41.95	10.64	31.31		
	41.93	10.65	31.28		
	41.93	10.65	31.28		
	41.92	10.68	31.24		
	41.90	10.67	31.23		
	41.90	10.67	31.23	31.29	420.75

gauge 22.07 × 21.7 = 206.2 + 10.6 = 412.4 ÷ 2 = 206.2

34.32

$q = 412.4$

$Q = 422.35$ $c = .976$

Time	H_1	H_2	$H_1 - H_2$	h	Q_1
1.26		16			
	46.40	4.98	41.42		
	46.28	5.01	41.27		
	46.28	5.01	41.27		
	46.25	5.03	41.22		
	46.25	5.03	41.22		
	46.24	5.05	41.19		
	46.24	5.03	41.21		
	46.22	5.05	41.17		
	46.21	5.05	41.16		
	46.20	5.08	41.12	41.225	482.98
	46.19	5.09	41.10		
	46.19	5.09	41.10		
	46.21	5.08	41.13		
	46.21	5.09	41.12		
	46.19	5.11	41.08		
	46.19	5.12	41.07		
	46.17	5.19	40.98		
	46.16	5.18	40.98		
	46.18	5.17	41.01		
	46.16	5.19	40.97	41.054	481.93
	46.15	5.19	40.96		
	46.13	5.18	40.95		
	46.12	5.19	40.93		
	46.11	5.19	40.92		
	46.11	5.19	40.92		
	46.09	5.20	40.89		
	46.12	5.21	40.91		
	46.09	5.25	40.84		
	46.06	5.25	40.81		
	46.04	5.30	40.74	40.887	480.44
	46.03	5.25	40.78		
	46.01	5.31	40.70		
	46.02	5.32	40.70		
	46.01	5.35	40.66		
	46.01	5.36	40.65		
	45.99	5.35	40.64		
	45.99	5.35	40.64		
	45.99	5.32	40.67		
	45.95	5.36	40.59		
	45.98	5.38	40.60	40.663	479.63
	45.98	5.40	40.58		
	45.99	5.39	40.60		
	45.94	5.39	40.55		
	45.92	5.49	40.43		
	45.90	5.45	40.45		
	45.89	5.50	40.39		
	45.89	5.48	40.41		
	45.86	5.49	40.37		
	45.85	5.52	40.33		
	45.85	5.52	40.33	40.484	478.57
	45.84	5.51	40.33		
	45.84	5.53	40.31		
	45.83	5.54	40.29		
	45.83	5.53	40.29		
	45.83	5.57	40.26		
	45.80	5.60	40.20		
	45.80	5.60	40.20		
	45.82	5.59	40.23		
	45.80	5.62	40.18	40.239	477.09

gauge 22.07 × 21.7 = 483.6 + 21.7 = 505.3 ÷ 2 = 252.6

8.64

$q = 471.2$

$Q = 480.19$ $c = .981$

Time	H_1	H_2	H_1-H_2	h	Q_1
2.65	47.23	3.85	43.38		
	47.18	3.86	43.32		
	47.15	3.87	43.28		
	47.18	3.87	43.31		
	47.14	3.88	43.26		
	47.12	3.90	43.22		
	47.13	3.89	43.24		
	47.12	3.89	43.22		
	47.10	3.93	43.17		
	47.08	3.92	43.16	43.256	494.73
	47.09	3.91	43.18		
	47.09	3.91	43.18		
	47.06	3.93	43.13		
	47.03	3.96	43.07		
	47.07	3.95	43.12		
	47.05	3.96	43.09		
	47.06	3.95	43.11		
	47.06	3.97	43.09		
	47.03	3.98	43.05	43.105	493.87
	47.03	4.00	43.03		
	47.00	3.99	43.01		
	47.00	4.01	42.99		
	47.00	4.00	43.00		
	46.99	4.02	42.97		
	46.99	4.01	42.97		
	46.98	4.02	42.96		
	46.97	4.02	42.95		
	46.98	4.03	42.95		
	46.95	4.05	42.90		
	46.92	4.10	42.82	42.953	492.95
	46.91	4.10	42.81		
	46.92	4.10	42.82		
	46.91	4.10	42.81		
	46.91	4.12	42.79		
	46.89	4.11	42.78		
	46.88	4.14	42.74		
	46.89	4.14	42.75		
	46.88	4.15	42.73		
	46.87	4.20	42.67		
	46.87	4.19	42.66	42.756	491.86
	46.86	4.19	42.67		
	46.85	4.21	42.64		
	46.86	4.20	42.66		
	46.85	4.22	42.63		
	46.84	4.23	42.61		
	46.83	4.23	42.60		
	46.82	4.23	42.59		
	46.82	4.23	42.59		
	46.81	4.25	42.56		
	46.81	4.25	42.56	42.611	490.99
	46.80	4.27	42.53		
	46.80	4.28	42.52		
	46.79	4.27	42.52		
	46.79	4.29	42.50		
	46.78	4.29	42.49		
	46.77	4.31	42.46		
	46.75	4.30	42.45		
	46.70	4.31	42.45		
	46.75	4.31	42.44	42.48	490.25
	gauge	20.63	241.2		
		34.97	.2		
			241.2		
	$q = 482$		2		
	$Q = 492.44$		482		
			$c = .979$		

Time	H_1	H_2	H_1-H_2	h	Q_1
3.28	48.95	1.42	47.53		
	49.10	1.31	47.79		
	49.08	1.35	47.73		
	49.04	1.38	47.66		
	49.02	1.38	47.64		
	49.01	1.41	47.60		
	48.98	1.42	47.56		
	48.99	1.42	47.57		
	48.97	1.43	47.54		
	48.97	1.43	47.54	47.616	519.06
	48.92	1.48	47.44		
	48.91	1.47	47.44		
	48.91	1.48	47.43		
	48.90	1.50	47.40		
	48.90	1.51	47.39		
	48.89	1.51	47.38		
	48.89	1.52	47.37		
	48.89	1.52	47.37		
	48.85	1.56	47.29		
	48.85	1.58	47.27	47.378	517.75
	48.84	1.61	47.23		
	48.83	1.65	47.18		
	48.80	1.66	47.14		
	48.80	1.66	47.14		
	48.80	1.68	47.12		
	48.80	1.69	47.11		
	48.79	1.69	47.10		
	48.75	1.70	47.05		
	48.76	1.69	47.07		
	48.73	1.70	47.03	47.115	516.33
	48.73	1.71	47.02		
	48.70	1.75	46.95		
	48.69	1.76	46.93		
	48.69	1.76	46.93		
	48.68	1.79	46.89		
	48.69	1.79	46.93		
	48.68	1.79	46.89		
	48.66	1.80	46.86		
	48.66	1.81	46.85		
	48.65	1.82	46.83	46.908	515.18
	48.65	1.84	46.81		
	48.63	1.86	46.77		
	48.63	1.90	46.73		
	48.60	1.90	46.70		
	48.61	1.91	46.70		
	48.61	1.92	46.69		
	48.59	1.93	46.66		
	48.59	1.93	46.66		
	48.59	1.90	46.69		
	48.58	1.91	46.67	46.708	514.08
	48.57	1.95	46.62		
	48.53	1.96	46.57		
	48.53	1.98	46.55		
	48.54	1.99	46.55		
	48.53	2.00	46.53		
	48.50	2.01	46.49		
	48.51	2.01	46.50		
	48.51	2.02	46.49		
	48.51	2.03	46.48	46.53	513.08
	gauge	20.63	6.23	49.54	
				241.2	
				254.2	
	$q = 508.4$			2	
	$Q = 515.91$			508.4	
			$c = .985$		

Time	H_1	H_2	H_1-H_2	h	Q_1
7.55			19.		
	49.72	.42	49.30		
	50.02	.15	49.87		
	49.99	.20	49.79		
	49.94	.19	49.75		
	49.93	.21	49.72		
	49.93	.20	49.73		
	49.90	.17	49.73		
	49.91	.22	49.69		
	49.89	.22	49.67		
	49.90	.23	49.67	49.692	530.22
	49.90	.22	49.68		
	49.89	.21	49.68		
	49.89	.22	49.67		
	49.88	.24	49.64		
	49.87	.25	49.62		
	49.87	.26	49.61		
	49.86	.26	49.60		
	49.86	.27	49.59		
	49.86	.27	49.59		
	49.84	.28	49.56	49.624	529.85
	49.83	.27	49.56		
	49.84	.29	49.55		
	49.82	.28	49.54		
	49.83	.30	49.53		
	49.83	.30	49.53		
	49.79	.34	49.45		
	49.80	.32	49.48		
	49.79	.33	49.46		
	49.79	.33	49.46		
	49.78	.33	49.45	49.521	529.21
	49.79	.32	49.47		
	49.79	.35	49.44		
	49.77	.33	49.44		
	49.75	.36	49.39		
	49.74	.37	49.37		
	49.74	.38	49.36		
	49.73	.38	49.35		
	49.73	.38	49.35		
	49.71	.39	49.32		
	49.71	.41	49.30	49.379	528.56
	49.71	.40	49.31		
	49.70	.40	49.30		
	49.69	.42	49.27		
	49.69	.43	49.26		
	49.68	.42	49.26		
	49.67	.46	49.21		
	49.67	.46	49.21		
	49.66	.47	49.19		
	49.66	.46	49.20		
	49.67	.45	49.20	49.241	527.82
	49.68	.47	49.21		
	49.67	.50	49.17		
	49.64	.49	49.15		
	49.65	.49	49.16		
	49.64	.50	49.14		
	49.63	.50	49.13		
	49.63	.51	49.12		
	49.62	.51	49.11		
	49.64	.54	49.10	49.140	527.28
	gauge 19.80		25 5.6		
		35.19	+ 3		
	$g = 517.2$	$c = .978$	25 8.6		
	$Q = 528.82$		2		
			517.2		

Time	H_1	H_2	H_1-H_2	h	Q_1
8.32		2a.			
	49.52	.75	48.75		
	49.66	.60	49.06		
	49.60	.61	48.99		
	49.59	.62	48.97		
	49.59	.62	48.97		
	49.58	.62	48.96		
	49.57	.64	48.93		
	49.58	.65	48.93		
	49.58	.67	48.91		
8.37	49.57	.66	48.91	48.838	525.67
	49.55	.67	48.88		
	49.54	.65	48.89		
	49.54	.66	48.88		
	49.52	.69	48.83		
	49.53	.70	48.83		
	49.51	.71	48.80		
	49.52	.74	48.78		
	49.51	.71	48.80		
	49.51	.70	48.81		
	49.48	.75	48.73	48.823	526.56
	49.49	.73	48.76		
	49.48	.76	48.72		
	49.48	.75	48.73		
	49.47	.78	48.69		
	49.45	.77	48.68		
	49.46	.78	48.68		
	49.46	.80	48.66		
	49.46	.79	48.67		
	49.45	.79	48.66		
	49.43	.79	48.64	48.689	524.86
	49.43	.81	48.62		
	49.43	.82	48.61		
	49.42	.82	48.60		
	49.41	.81	48.60		
	49.41	.82	48.59		
	49.40	.83	48.57		
	49.41	.82	48.59		
	49.40	.83	48.57		
	49.39	.85	48.54		
	49.38	.85	48.53	48.582	524.27
	49.39	.87	48.52		
	49.38	.87	48.51		
	49.38	.87	48.51		
	49.37	.88	48.49		
	49.37	.89	48.48		
	49.35	.89	48.46		
	49.34	.91	48.43		
	49.34	.90	48.44		
	49.33	.90	48.43		
	49.33	.91	48.42		
	49.33	.90	48.43		
	49.33	.92	48.41		
	49.32	.93	48.39		
	49.32	.94	48.38		
	49.32	.93	48.38		
	49.32	.94	48.38		
	49.31	.95	48.36	48.40	523.29
	gauge 5.19		5 13.8		
	19.80		25 5.6		
			25 8.2		
	$g = 516.4$		2		
	$Q = 524.55$		516.4		
			$c = .984$		

Specimen calculation of Table 4 experiment 20

$Q = 75.218\sqrt{H_1 - H_2}$ $\qquad \log 75.218 = 1.8763226$

" $\sqrt{48.838}$ $\qquad \log\sqrt{48.838} = 1.8443878$

525.67 $\qquad$ 2.7207104

$Q =$ " $\sqrt{48.823}$ $\qquad$ 1.8763226 + 1.8442989 = 2.7206215

525.56

$Q =$ " $\sqrt{48.689}$ $\qquad$ 1.8763226 + 1.8437199 = 2.7200425

524.86

$Q =$ " $\sqrt{48.582}$ $\qquad$ 1.8763226 + 1.8432287 = 2.7196513

524.27

$Q =$ " $\sqrt{48.472}$ $\qquad$ 1.8763226 + 1.8427365 = 2.7190591

523.67

$Q =$ " $\sqrt{48.40}$ $\qquad$ 1.8763226 + 1.8424227 = 2.7187453

525.67
525.56
524.86
524.27
523.67
523.29

6 | 3147.32

524.55

$Q = 524.55$ cu ft per hr.

gauge 5.19
19.80

513.8
2.6
516.4

$q = 516.4$ cu ft per hr.

$c = \frac{q}{Q} = \frac{516.4}{524.55}$ $\qquad$ 2.7129862 − 2.2802131 = $\bar{1}.9931993$

$c = .98446$

The results of experiment number four have been plotted graphically with a view to rendering more readily apparent the relation existing between the discharge and the head on the venturi. The curve will be found at the end of this record of experiments. The abscissae of the curve are cubic feet of discharge per minute while the ordinates represent inches of mercury on the manometer. Two distinct curves will be found The one in black represents the relation between the theoretical discharge and the pressure while the red curve shows the same relationship for the actual discharge. It will

be noticed that these two curves approach each other at a constant rate indicating a uniform variation in the value of the coefficient of discharge. Owing to the variation of head during this series of experiments the value of c or coefficient of discharge in various experiments is not directly comparable but as above the curves of discharge indicate a constant variation in the value of c which would make a straight line curve for its graphic representation. The value of c varies from .950 to .985.

That the value of the coefficient of discharge is not a direct function of the head on the venturi will be readily seen from a

UNIVERSITY of PENNSYLVANIA LIBRARIES

consideration of the data in experiments number nineteen and twenty in table four. In experiment nineteen with the regulating valve about two thirds open a larger discharge viz. 517.2 cu. ft. per hour was obtained than in experiment twenty with the controlling valve wide open when 516.4 cu ft were obtained due to about one half inch of mercury pressure less in the second case than in the former. If the value of the coefficient of discharge is in the second case .984 and in the first instance .978 indicating the effect of the condition of the valve on the discharge.

It ought not was not possible to maintain a constant head

on the return during this series of experiments. This does not in any way affect the curves of discharge obtained. In any subsequent experiments on the variation of the value of c. it is evident that the research should be made along two lines - 1. Constant head and varying valve opening. 2. Constant valve opening - preferably full open - and varying head.

E378.748 P051897.7

FOR REFERENCE

NOT TO BE TAKEN FROM THIS ROOM

CAT. NO. 1935 LIBRARY BUREAU

3 1198 03076 5775
N/1198/03076/5775X